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PII: S0273-2300(07)00144-4
DOI: 10.1016/j.yrtph.2007.09.013
Reference: YRTPH 2060

To appear in: *Regulatory Toxicology and Pharmacology*

Received Date: 5 September 2007
Accepted Date: 30 September 2007

Please cite this article as: Whitep, N., Nelson, G., Murray, J., South African experience with asbestos related environmental mesothelioma: Is asbestos fiber type important?, *Regulatory Toxicology and Pharmacology* (2007), doi: 10.1016/j.yrtph.2007.09.013

South African experience with asbestos related environmental mesothelioma: Is asbestos fiber type important?

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Abstract

South Africa (SA), a country in which all three commercially important asbestos minerals have been mined and milled has retained proven cases of mesothelioma linked with environmental exposure to asbestos. This study illustrates the importance of fiber type in the occurrence of environmental mesothelioma. Four studies have reviewed the source of occupational or environmental asbestos exposure in 504 histologically proven cases of mesothelioma in South Africa. One hundred and eighteen cases (23%) were thought to be related to environmental exposure to asbestos. In the vast majority of these cases, exposure was linked to crocidolite mining activities in the Northern Cape Province. Two cases were thought to have occurred in relation to amosite and Transvaal crocidolite exposure in the Limpopo Province. In the balance of cases there was some uncertainty. No cases were reported with exposure to South African chrysotile. Consequently, in the vast majority of cases of mesothelioma, environmental exposure to asbestos occurred in the Northern Cape Province, in proximity to mines, mills and dumps where crocidolite was processed. Crocidolite appears to be far more mesotheliomagenic than amosite, and chrysotile has not been implicated in the disease. This is true for both occupationally and environmentally exposed individuals.

Keywords: Crocidolite; Mesothelioma; Chrysotile; Amosite; South Africa

1. Introduction

All three of the major commercial forms of asbestos , viz. crocidolite (blue asbestos), amosite (brown asbestos) and chrysotile (white asbestos) occur and have been mined and milled in South Africa. Crocidolite was mined in the Northern Cape Province (Cape crocidolite) and in Limpopo Province (Transvaal [Tvl] crocidolite). Amosite was mined in close proximity to Transvaal crocidolite and chrysotile in Mpumalanga Province. Both amosite and crocidolite belong to the amphibole group of asbestos minerals, whereas chrysotile is a serpentine asbestos mineral.

Mining of asbestos in South Africa began in the 19th century and reached its zenith in 1977 when South Africa exported more than 380, 000 tons of asbestos, making it the 3rd biggest supplier in the world in that year (Harington and McGlasham, 1998). Production declined steadily thereafter and by 1992 South Africa was only the 7th largest world supplier of asbestos. By 2002 asbestos mining in South Africa had ceased completely.

A variety of transnational companies dominated asbestos mining in South Africa. From the onset of the scientific examination of the health effects of asbestos mining in South Africa, it became apparent that the primitive technologies employed in mining and particularly milling, ignorance about the health effects of asbestos and lack of enforcement by responsible government departments created widespread opportunities for environmental contamination and subsequent exposure of people who were not employed in the industry.

2. History of mesothelioma in South Africa

During the 1959 Pneumoconiosis conference in Johannesburg, South Africa, Dr. J. Christopher Wagner gave the first public presentation of five cases of mesothelioma connected with exposure to asbestos. During his presentation, he suggested that a fuller investigation be conducted to examine the relationship between mesothelioma and asbestos (Wagner, 1960).

A year later, in 1960, Wagner, Sleggs and Marchand published their renowned article in the British Journal of Industrial Medicine documenting thirty-three cases of mesothelioma, thirty-two of whom had proven exposure to Cape crocidolite. Eight of the thirty-three cases had evidence of occupational exposure; twenty were born or lived near the mines as children. This was the first evidence implicating a specific fiber (Cape crocidolite) in the development of mesothelioma (Wagner et al., 1960). What became one of the greatest occupational health discoveries of the twentieth century was based principally on cases drawn from outside the workplace. By 1961, Wagner had collected eighty-nine cases in South Africa.

Despite this strong evidence, Wagner's work had little impact on work practices in South Africa, and workers and communities alike continued to be exposed to high fiber levels. More than 25 years passed before the first asbestos regulations were promulgated in South Africa.

During the 1961/ 1962 survey undertaken by the Pneumoconiosis Research Unit (now the National Institute for Occupational Health), disease rates in 2,389 residents of Prieska, Koegas, Kuruman (Cape crocidolite mining areas) and the Penge group of mines (amosite) were compared with those in a control group living in a town two-hundred kilometers from the asbestos mining areas (Pneumoconiosis Research Unit, 1964). The results identified a hazard for every person living in these four small-town communities. The four mesothelioma cases detected in Prieska translated into a much higher than expected rate of the disease. No cases were reported

in Penge residents. In an interim report the Pneumoconiosis Research Unit stated: "people who live or have lived in the areas of Prieska , Koegas, Kuruman and Penge are in danger of contracting asbestosis even though they have had no industrial exposure to asbestos dust inhalation" and "an alarmingly high number of cases with mesothelioma of the pleura has been discovered among people who live or have lived in the north western Cape area [now the Northern Cape Province] and that there is evidence to suggest that this condition is associated with an exposure to asbestos dust inhalation which again need not be industrial" (Pneumoconiosis Research Unit, 1962).

Exposure to asbestos occurred primarily through community use of the fibers. Tailings were used for many purposes, including road surfacing, golf courses, and brick and plaster making. Fibers were used as insulation material in residential ceilings and children played on fiber-rich waste ground. This association of mesothelioma with residential asbestos exposure has been borne out by more recent work in towns like Koegas and Prieska in the Northern Cape (Kielkowski et al., 2000).

This paper reviews the South African experience of mesotheliomas in relation to environmental asbestos exposure.

3. Review of the literature

Despite the fact that South Africa has uniquely mined, transported and used crocidolite, amosite and chrysotile, and that mesothelioma rates are relatively high, there is a paucity of local epidemiological studies of this disease.

Four studies detail the occupational and environmental exposure of 504 histologically proven cases of mesothelioma in South Africa (Webster, 1973; Cochrane and Webster, 1978; Solomons, 1984; Rees et al., 1999). Two further studies add to the estimate of the overall risk of environmental mesothelioma (Zwi et al., 1989; Kielkowski, et al., 2000), and the reports of the South African National Cancer Registry (SANCR) enable some estimation of the overall burden of mesothelioma in South Africa until 1992. All sources indicate that there is under-reporting of mesothelioma to official sources of data collection, as well as to workers' compensation authorities. It is also evident that there are marked differences in mesothelioma rates by race and geographic origin.

Sources suggest that incidence rates of mesothelioma in the white female population give some indication of occurrence of mesothelioma related to environmental exposures (Zwi et al., 1989), as most of the workers employed in the mining industry were men, as well as black and colored women and children.

Table 1 gives standardized incidence rates of mesothelioma in the population of South Africa at two time periods, by race and sex. For whites, for whom data are most reliable, incidence rates increased from the 1976 to 1984 period and then through 1992. The 1992 white female mesothelioma incidence increased from 8.9 to 20.8 per million per year. These data suggest that there is an increasing incidence of mesothelioma as a consequence of both environmental and occupational exposure.

Table 2 is a summary of occupational and environmental asbestos exposure in 504 histologically proven cases of mesothelioma in South Africa. The first three papers are case-series reports; the only analytical study was conducted by Rees et al., 1999. The overall proportion of cases resulting from environmental exposure to asbestos in the four studies in Table 2 is high, at 23%.

In the earliest review by Webster (1973), a significant proportion of cases had either unknown exposure or no exposure identified. Subsequently, there has been better ascertainment of exposure and fewer cases in these categories. Webster identified seventy-six (32% of a total of 232 cases) environmentally exposed cases of mesothelioma in the period 1955 to 1970. Mining and non-mining occupationally exposed cases comprised 44% of the mesotheliomas.

Cochrane and Webster (1978) studied 70 cases of mesothelioma diagnosed before 1978. Thirteen of the sixty-nine for whom there was substantive evidence of asbestos exposure had only environmental exposure, defined as a minimum of three years residence in a mining area, or in a town where exposure occurred from playing on "asbestos fields" or tailings dumps as a child.

Solomons (1984) identified eighty cases of histologically confirmed mesothelioma in the period from 1977 to 1983. In 89% of cases, he elicited a positive history of exposure. His definition of environmental exposure included childhood, domestic, neighborhood or any other definite exposure that was not occupational. Seven of the eight cases had a history of only environmental exposure.

Rees et al., (1999) conducted a multi-centre case control study over the period 1988 to 1990. In total, 123 cases of histologically confirmed mesothelioma were identified. Twenty-two (18%) of these cases had exclusively environmental exposure in the Cape crocidolite asbestos mining region, i.e. exposure due to contamination of the general environment by asbestos mining, milling and related activities (Table 3). The remaining two environmentally exposed cases had mixed fiber (amosite and Transvaal crocidolite) exposures.

Unfortunately, not all the authors provided the same detail on the specific fiber types to which individuals were exposed, especially with regard to environmental exposure. Table 3 provides a more detailed picture of fiber-specific exposure, for those studies for which this information was provided. Exposures are defined as occupational or environmental, according to the authors' definitions. Webster (1973) defined environmental cases as those who had lived (or spent time) in the neighborhood of an asbestos mine or mill, or in geographical areas suggestive of possible asbestos exposure. Cochrane and Webster (1978) classified cases as environmentally exposed if they had lived in an asbestos mining or milling area for a minimum of three years. Solomon's (1984) definition included childhood, domestic, neighborhood or other definite exposure which was not occupational. In the study conducted by Rees et al., (1999), 22 environmentally exposed cases were exposed in one of the three main asbestos mining regions. Domestic exposure to asbestos was not included under environmental exposure. Apart from Rees et al., (1999), none of the authors were able to provide information on the geographical regions from which the cases originated or in which they may have lived.

In a separate study, not depicted in Table 2, Zwi et al., (1989) identified 1,347 cases for the period 1976 to 1984. Only 17% (ninety-six) of cases occurring in men (where asbestos exposure was documented) were environmental; in women, 124 of 176 cases (70%) were considered to be solely due to environmental exposure.

Many questions about mesothelioma in South Africa remain unanswered. Among them are the relative contribution each variety of asbestos makes to the case load, the extent and nature of asbestos exposure in a representative group of cases (e.g. the proportion of cases with purely environmental exposure), and the relative risks associated with the different fiber types and exposure settings.

Webster (1973) was able to ascertain the fiber type in seventy-eight of the seventy-nine occupationally exposed cases. Amosite was implicated in three and Cape crocidolite in seventy-

five of these cases. He did not report fiber types in any of the seventy-six environmentally exposed cases. Cochrane and Webster (1978) did not identify the fiber type to which any of the occupational cases had been exposed, but Cape crocidolite was implicated in all thirteen of the environmentally exposed cases. Solomons (1984) was able to implicate fiber type in twenty-one of the sixty-eight occupationally exposed cases; seventeen of these were due to Cape crocidolite and four to amosite exposure. There was no information on fiber types given for the environmentally exposed group.

Rees et al., (1999) however, provided information on fiber type (where it could be elicited) for both occupationally and environmentally exposed individuals. Amosite exposure was reported in three miners (10%), but in none of those environmentally exposed. In twenty-three (77%) of those occupationally exposed and twenty (91%) of those environmentally exposed, Cape crocidolite was identified as the responsible fiber. There were no cases of mesothelioma where exposure (occupational or environmental) was to chrysotile only.

Rees et al., (1999) also calculated relative risks for mesothelioma in response to different fiber types. The relative risks associated with environmental exposure to Cape crocidolite were larger than those associated with environmental exposure to a mixture of amosite and Transvaal crocidolite, viz. 21.9 and 7.1, respectively when compared with cancer controls, and 50.9 and 12.0, respectively when compared with medical controls.

4. Discussion

South Africa, as a former asbestos mining country, in common with many other countries in the world, has high incidences of mesothelioma (Table 1). A high proportion of mesothelioma cases solely of environmental origin (23%) are unique to South Africa. The only comparable example is Australia, the only other country to have mined crocidolite asbestos in significant amounts. Ferguson et al., 1987 found that, in 726 cases of mesothelioma registered in Western Australia from 1980 to1985, forty-three cases (6%) had environmental exposure only, and only in six (less than 1%) was environmental asbestos exposure due to residence in an asbestos mining region.

No confirmed cases of mesothelioma have been detailed in the literature with relation to South African chrysotile mining. There is a high prevalence of cases from the Cape crocidolite mining region. The lower number of reported cases from Limpopo Province (where amosite and Transvaal crocidolite were mined) is not linked to the sizes of the two workforces. At the height of production, the numbers employed in the amosite and Cape crocidolite mines were comparable (Sluis-Cremer, 1965).

The association between amosite exposure and mesothelioma is evident. However, this review of environmental association of asbestos with mesothelioma in South Africa suggests that crocidolite is considerably more mesotheliomagenic than amosite. Fiber type was determined in thirty-five of the 118 environmentally exposed cases reported in these four papers. Of these, thirty-three (94%) had been exposed to Cape crocidolite. Only two cases had environmental exposure to amosite; both had also been exposed to crocidolite. In a study of the causes of death in a cohort of South African amphibole miners, the proportional mortality ratio for mesothelioma was 4.7% in the crocidolite miners, compared to 0.6% in amosite miners (Sluis-Cremer, 1992).

Past occupational exposures in the mining industry in South Africa, given the imperfect historical record, were at times astonishing by modern standards. These exposures conferred an

enormous risk of malignant and non-malignant asbestos related disease on workers employed by the asbestos mining industry, as well as on residents in the mining areas.

5. Conclusion

In conclusion, a review of the fiber associations of environmental mesothelioma indicates that asbestos fiber type is important. There have been no reported cases associated with chrysotile in South Africa. Amphiboles occurring in the Limpopo Province of South Africa, namely amosite and Transvaal crocidolite, have been linked to environmental mesothelioma in the papers reviewed. The vast majority of environmental mesothelioma cases in South Africa, where fiber type is known, have occurred in relation to crocidolite mining activities in the Northern Cape Province and, consequently, at the low dose range of exposure, it must be concluded that this fiber type represents the greatest hazard to human health.

References

Annual Reports of the National Cancer Registry (NCR) of South Africa *SAIMR*, 1986-1992. Cancer in South Africa. Johannesburg.

Cochrane, J.C., Webster, I., 1978. Mesothelioma in relation to asbestos fibre exposure. S. Afr. Med. J. 54, 279-281.

Ferguson, D.A., Berry, G., Jelihovsky, T., Andreas, S.B., Rogers, A.J., Fung, S.C., Grimwood, A., Thompson, R., 1987. The Australian mesothelioma surveillance program 1979 – 1985. Med. J. Aust. 147, 166-172.

Harington, J.S. and McGlashan, N.D., 1998. South African asbestos: production, exports, and destinations, 1959-1993. Am. J. Ind. Med. 33, 321-326.

Kielkowski, D., Nelson, G., Rees, D., 2000. Risk of mesothelioma from exposure to crocidolite asbestos: a 1995 update of a South African mortality study. Occup. Environ. Med. 57, 563-567.

Pneumoconiosis Research Unit, 1964. Field survey in the North Western Cape and at Penge in the Transvaal (asbestosis and mesothelioma). Report No. 1.

Pneumoconiosis Research Unit, South African Council for Scientific and Industrial Research, unpublished. Report on the progress of mesothelioma survey as at 30 April 1962.

Rees, D., Myers, J.E., Goodman, K., Fourie, E., Blignaut, C., Chapman, R., Bachman, M.O., 1999. Case-control study of mesothelioma in South Africa. Am. J. Ind. Med. 35, 213-222.

Sluis-Cremer, G.K., 1965. Asbestosis in South Africa – certain geographical and environmental considerations. Ann. N.Y. Acad. Sci. 132, 215 – 234.

Sluis-Cremer, G.K., Liddell, F.D.K., Logan, W.P.D., Bezuidenhout, B.N., 1992. The mortality of amphibole miners in South Africa 1946-80. Br. J. Ind. Med. 49, 566-575.

Solomons, K., 1984. Malignant mesothelioma – clinical and epidemiological features: A report of 80 cases. S. Afr. Med. J. 66, 407-412.

Wagner, J.C., 1960. Some pathological aspects of asbestosis, in: Orenstein, A.J. (Ed.), Proceedings of the Pneumoconiosis Conference held at the University of the Witwatersrand, Johannesburg, 9-24 February 1959. J&A Churchill Ltd, London, pp. 1- 378.

Wagner, J.C., Sleggs, C.A., Marchand, P., 1960. Diffuse pleural mesothelioma and asbestos exposure in the North West Cape Province. Br. J. Ind. Med. 17, 260 – 265.

Webster, I., 1973. Asbestos and malignancy. S. Afr. Med. J. 47, 165-171

Zwi, A.B., Reid, G., London, S.P., Kielkowski , Sitas F., Becklake, M.R., 1989. Mesothelioma in South Africa, 1976-84: Incidence and case characteristics. Int. J. Epidemiol. 18, 320-329.

Table 1: Standardized incidence rates per million population aged 15 years and over for mesothelioma in South Africa by race and gender

	White		Colored		Black	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Overall 1976 – 84*	32.9	8.9	24.8	13.9	7.6	3.0
95% CI 1976 - 84	22.7-46.4	2.5-15.8	16.2-36.9	7.7-23.5	3.5-15.8	0.6-8.8
1992**	54.0	20.8	5.2	2.4	6.4	6.0

*1976 – 1984 data: Zwi et al., 1989.
**1992 data: Annual Reports of the National Cancer Registry of South Africa, 1992.

Table 2: Summary of occupational and environmental asbestos exposure in 504 histologically proven cases of mesothelioma in South Africa

Exposure source	**Webster, 1973**	**Cochrane and Webster, 1978**	**Solomons, 1984**	**Rees et al., 1999**	**Total**
Mining	79 (34%)	16 (23%)	15 (19%)	35 (28%)	145 (28%)
Non-mining occupational	23 (10%)	39 (57%)	53 (66%)	62 (50%)	177 (35%)
Environmental	76 (32%)	13 (19%)	7 (9%)	22 (18%)	118 (23%)
No exposure	32 (14%)	1 (1%)	5 (6%)	3 (2%)	41 (8%)
Exposure not known	22 (9%)	-	-	1 (1%)	23 (5%)
Total cases	**232**	**69**	**80**	**123**	**504**

Table 3. Fiber types implicated in the development of mesothelioma

Fiber type	Webster, 1973		Cochrane and Webster, 1978		Solomons, 1984		Rees et al., 1999		All	
	Occ	**Env**	**Occ**	**Env**	**Occ**	**Env**	**Occ**	**Env**	**Occ**	**Env**
Cape crocidolite	75	-	-	13	17	-	23	20	115	33
Tvl crocidolite	-	-	-	-	-	-	1	-	1	-
Amosite	2	-	-	-	4	-	3	-	9	-
Chrysotile	-	-	-	-	-	-	-	-	-	-
Mixed fiber type	1*	-	-	-	-	-	3	2†	4	2
Undetermined	1	76	16	-	47	7	-	-	64	83
Total	**79**	**76**	**16**	**13**	**68**	**7**	**30**	**22**	**193**	**118**

* amosite + Cape crocidolite
† Transvaal crocidolite + amosite